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CURRENT GASIFICATION POWER PLANT PROJECTS

There are currently at least 35 GPP projects in operation, commissioning, construction, design or planning. These vary in size from $500MW_e$ to less than $10MW_e$ and use a variety of fuels such as coal, heavy oil residues, waste woods, sewage sludge and sugar cane bagasse. A selection of these projects are reviewed below whilst a full list of operational and near-operational plant is given in Table 3.

Coal GPPs

Buggenum (Netherlands)

The Buggenum plant is the world's first commercial-sized ($253MW_e$), coal-fired IGCC (Figure 11). The IGCC is based around a Shell SCGP gasifier and a CCGT supplied by Siemens. The plant was started up in 1993. As well as being the first of the current generation of IGCC plant, the project is important in that it contains a number of advanced design features. The most significant of these is that the ASU and the gas turbine are very closely coupled together, with the gas turbine compressor supplying all the air to the ASU. This increases efficiency at the cost of making the plant more complex and less easy to start

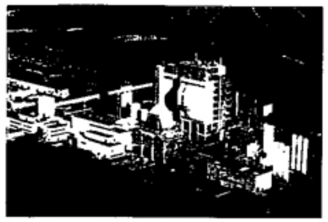

Figure 11 Buggenum IGCC (courtesy of Demkolec)

Name	Location	Output(MW)	Fuel	Gasifier	Power Island	1998 Status	Year
Buggenum	Netherlands	$253MW_e$	Bituminous coal	Shell	CCGT - V94.2	Operational	1995
Piñon Pine	USA	$100MW_e$	Bituminous coal	KRW	CCGT - GE 6FA	Commissioning	1998
Polk	USA	$250MW_e$	Bituminous coal	Texaco	CCGT - GE 7F	Operational	1996
Puertollano	Spain	$298MW_e$	Coal and petroleum coke	Prenflo®	CCGT - V94.3	Commissioning	1998
Vaesová	Czech Republic	$400MW_e$	Lignite	Lurgi	CCGT - 2xGE 9E	Operational	1995
Wabash River	USA	$262MW_e$	Bituminous coal	Destec	CCGT - GE 7FA	Operational	1995
El Dorado	USA	$40MW_e$ (gross)	Petroleum coke	Texaco	GT - GE 6B	Operational	1996
Falconara	Italy	$234MW_e$	Visbreaker residues	Texaco	CCGT - ABB 13E2	Construction	1999
GSK	Japan	$550MW_e$	Vacuum residue	Texaco	CCGT - 2xGE 9EC	Construction	2000
Pernis	Netherlands	$125MW_e$	Refinery residues	Shell SGP	CCGT - 2xGE 6B	Operational	1997
Priolo Gargallo	Italy	$521MW_e$	Refinery asphalt	Texaco	2xCCGT V94.2	Construction	1999
Saras	Italy	$550MW_e$	Visbreaker residue	Texaco	CCGT - 3xGE 9E	Construction	2000
Star	USA	$240MW_e$	Petroleum coke	Texaco	2xGE 6FA	Construction	1999
Amercentrale	Netherlands	$85MW_{th}$	Wood wastes	Lurgi CFB	Existing boiler	Construction	2000
ARBRE	UK	$8MW_e$	SRC willow	TPS CFB	CCGT - AGT typhoon	Construction	1999
Energy Farm	Italy	$12MW_e$	Short rotation forestry	Lurgi CFB	CCGT - Nuovo Pignone PGT10B/1	Construction	2000
Lahti	Finland	$70MW_{th}$	Wood wastes	Foster Wheeler CFB	Existing boiler	Operational	1998
McNeil	USA	$\sim 15MW_{th}$	Wood chips	Battelle CFB	Existing boiler	Operational	1997
Värnamo	Sweden	$6MW_e$	Wood wastes	Foster Wheeler CFB	CCGT - AGT Typhoon	Operational	1993
Fondotoce	Italy	$1MW_e$	MSW	Thermo-select (moving bed)	Gas-motor generator	Operational	1994
Grève in Chianti	Italy	$6.7MW_e$ (gross)	Refuse - derived fuel	TPS CFB	Boiler and steam turbine	Operational	1992
New Bern	USA	$<60MW_{th}$	Black liquor	Chemrec (entrained flow)	Boiler and steam turbine	Operational	1997
Schwarze Pumpe	Germany	$60MW_e$	Assorted solid and liquid wastes	Noell, Lurgi BGL	CCGT - GE Frame 6	Operational. BGL to start-up in 1999	1997
Westfield	UK	120MW	Sewage sludge plus coal	BGL	CCGT - GE 6B	GT Operational on natural gas	1998
Zeltweg	Austria	$10MW_{th}$	Biomass/wastes	AE&E CFB	Existing boiler	Operational	1997

Table 3 Operational and near-operational GPPs

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Westfield (UK)

The site of British Gas' Westfield Development Centre in Fife is being developed by the US-based Fife Power. The existing BGL gasifiers on the site are being refurbished to gasify a mixture of coal and sewage sludge. When the plant is fully operational, it will generate ~120MW$_e$

In a second project at the same site, Fife Power plans to build a 400MW$_e$ unit, also using BGL gasifiers, to gasify coal and household refuse.

FUTURE PROSPECTS

Market Opportunities

Coal

The most important markets for new coal-fired plant over the next 10-15 years will be China and South and East Asia. However, overwhelmingly in these markets, the technology chosen will be conventional pf-fired boilers as the primary pre-requisites for these markets are low capital cost and high reliability, as well as the need to locally-source equipment wherever possible. The most important markets for IGCC will be North America (8-16GW$_e$) and China (6-8GW$_e$), the former driven by stringent emissions limits, the latter by the sheer amount of new capacity required. The uptake of IGCC in Europe will be constrained by the widespread availability of cheap natural gas. Overall, coal-fired IGCC will represent no more than 10% of new coal-fired plant worldwide until its costs are significantly lowered and its reliability increased.

Oil and Petroleum Coke

There is considerable scope in the short-to-medium term for oil- and petroleum coke-fired IGCCs plant integrated with refinery processes. The key drivers are the refiners' need to find routes for the disposal of heavy oil residues and petroleum coke and their need for H_2 to upgrade other refinery products. There is scope for up to 14GW$_e$ of oil-fired IGCC in the European Union (EU) by 2010 (based on the amount of heavy residue likely to be available). However, the actual oil-IGCC capacity in the EU will be constrained by the availability of natural gas, which is an alternative source of H_2. Another significant market may be India: there, the deployment of oil-IGCC will depend on being able to get reliable and secure power purchase agreements (PPAs). In the short-to-medium term, oil-IGCC plant may well out-number coal IGCC plant.

Biomass

Biomass is becoming increasingly important as a fuel in both the EU and the USA because of concerns over CO_2 emissions. For biomass GPPs to make headway, they will have to become more cost-competitive relative to biomass combustion plant. Typical projects will be combined heat and power schemes utilising agricultural and forestry residues, eg in remote areas of Scandinavia, China, Canada, India and Brazil.

Waste

Gasification is an excellent, if expensive, way to dispose of wastes such as MSW and sewage sludge, both 'neat' and co-gasified with coal. It has several significant advantages over waste incineration, such as producing only an inert solid residue and eliminating the potential for the production of dioxins. Waste gasification will first 'take off' in those parts of Europe with particularly strong environmental concerns over waste incineration, such as Germany and Switzerland. By 2010, perhaps 15% of new waste disposal plant in Europe will be based on gasification.

A further application of the gasification of biomass and wastes is the production of fuel-gas for the partial repowering of existing oil- and coal-fired boilers. Several schemes are already in operation. Biomass and wastes cannot be used directly in conventional boilers. Their low or negative cost can make them attractive fuels in principle but they cannot be fired, as they cannot be ground finely enough. Air-blown gasification converts them into a fuel-gas that can be fired in the boiler, providing a means of waste disposal.

Research and Development Needed

The current weaknesses of GPP technologies are high capital costs, poor reliability (at least for coal-fired IGCCs) and poor operational flexibility. The current strengths are high efficiency and environmental performance. It is therefore clear that, in the short-to-medium term, R&D effort needs to be focused on reducing costs and increasing reliability and operability. This R&D effort can be broken down into three major areas:

- i research into the fundamentals of gasification
- ii R&D to improve individual plant components
- iii R&D into better overall process layout and design

Research into the fundamentals of gasification is required to establish the fuel flexibility of IGCC technologies. This would be directed at understanding gasification reaction rates and carbon conversion and at predicting the gasifiability of individual coals and other fuels, ash/slag behaviour and the potential for sulphur capture in fluidised bed gasifiers.

R&D is required to improve the following components of IGCC, to make them more reliable and/or cheaper:

- gasifiers/syngas coolers
- pressurised coal feeding systems
- gas clean-up
- gas turbines
- ASUs.

The required R&D for gasifiers and syngas coolers is centred on the development of improved alloys and manufacturing processes to improve the corrosion resistance and lower the cost of these components.

Pressurised coal feeding systems (both dry pf systems and briquetting systems) need to be improved to increase reliability and lower costs.

The development of improved hot gas clean-up systems could lower the cost of IGCC by providing a cheaper alternative to the conventional low-temperature processes currently employed. R&D is required to improve the reliability of both hot gas filters and hot gas desulphurisation systems.

The highest priority gas turbine R&D for IGCC is the development of better combustion systems for low-CV syngas. Also required is the development of more rugged gas turbines, capable of reliably running on uncleaned or partly-cleaned syngas.

Further work is required to allow the successful integration of ASUs into an IGCC. The two areas requiring attention are improved control systems for, and better dynamic simulation of, highly integrated ASUs. There is also the need, in the longer term, for alternatives to conventional cryogenic ASUs in order to lower costs.

A key area of R&D for IGCC is optimisation of the overall plant configuration and layout. Specific issues that require study are:

- dynamic simulation
- start-up and shut-down strategies
- operability
- simplified designs which reduce cost
- optimum integration strategies
- combining operability assessments within existing thermo-economic optimisation techniques.

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TAB 2

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PSC Request 2
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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 2
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 2. Provide a copy of the Tender Specification Documents ("TSD") of the construction contractor. Provide the design and engineering of the process if it is not included in the TSD. Were the characteristics of Kentucky-produced coal considered in the selection of the type of process and equipment?

Response 2. Kentucky Coal has qualities well suited for use by the Kentucky Pioneer Project. Kentucky Coal and other fuel components are included in all design work.

The PSD Permit Application to the Commonwealth of Kentucky, Department of Environmental Protection (DEP), and anticipated permit conditions, contain substantial design information for the project. Department of Air Quality (DAQ) within DEP is preparing a Draft Permit for public comment. Since the air permit is a prerequisite to project financing, there is ample opportunity to effectively reflect environmental requirements in the plant design.

Kentucky Pioneer Energy project design information is subject to international contractual secrecy agreements and is therefore business confidential and not available.

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TAB 3

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PSC Request 3
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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 3
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 3. Provide the estimated budget for the project.

Response 3. The direct costs associated with engineering, major equipment and construction of the project are estimated at $470 million.

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TAB 4

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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 4
RESPONSIBLE PERSON: Dwight Lockwood
COMPANY: Kentucky Pioneer Energy
(responding for East Kentucky Power Cooperative)

Request 4. Provide the preliminary schedule for the project and estimated date of construction.

Response 4. Kentucky Pioneer Energy expects commercial operation after a 36-month engineering, procurement and construction period following financial closure in late 2000.

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TAB 5

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PSC Request 5
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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 5
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 5. Provide the ratio of the coal to solid waste.

Response 5. The AFT briquette Coal to RDF ratio can vary and will depend upon economic considerations, component qualities, and desired performance. Kentucky Pioneer Energy anticipates a ratio ranging from 2:1 to 1:1 RDF to Coal.

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TAB 6

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EAST KENTUCKY POWER COOPERATIVE, INC.
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INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 6
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 6. Will the solid waste be combined with coal to produce a briquette or will the solid waste be converted into gas and then processed with the coal? Explain the process to be used.

Response 6.
Typically the fuel briquette mixture of Kentucky Coal and RDF will be gasified, though a feed of coal is also feasible. Solid feed material will be gasified and the syngas will then be purified before use as combustion turbine fuel.

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TAB 7

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EAST KENTUCKY POWER COOPERATIVE, INC.
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INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 7
RESPONSIBLE PERSON: Dwight Lockwood
COMPANY: Kentucky Pioneer Energy
(responding for East Kentucky Power Cooperative)

Request 7. Will Kentucky coal be used exclusively for the briquettes? If yes, describe the term of contracts that are expected to be signed.

Response 7. Kentucky Pioneer Energy intends to exclusively use Kentucky Coal. Long-term (i.e. 20 year) supply contracts are planned.

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TAB 8

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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 8
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 8. How much coal and how much solid waste are anticipated to be utilized on an annual basis?

Response 8. Assuming a 50/50 blend of Kentucky Coal and RDF, annual consumption would approach:

Coal:	1 million tons per year
RDF (MSW):	1 million tons per year

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TAB 9

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PSC Request 9
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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 9
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 9. Where will the solid waste and coal be stored and where will the briquettes be made?

Response 9. The briquette production facility location has not yet been selected. Storage of solid waste components will be avoided by just-in-time delivery. Receipt of solid waste is planned to be indoors in a negative pressure building – followed by immediate processing. Coal supplies will be staged sufficient to support briquette production upon receipt of MSW.

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TAB 10

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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 10
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 10. Will all the solid waste originate in Kentucky or will out-of-state solid waste be imported?

Response 10. The relatively small amounts and generally widely dispersed nature of MSW in the Commonwealth (i.e. small quantities in each county) does not economically support exclusive utilization of Kentucky generated MSW supplies.

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TAB 11

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EAST KENTUCKY POWER COOPERATIVE, INC.
PSC CASE NO. 2000-079
INFORMATION REQUEST RESPONSE

PUBLIC SERVICE COMMISSION REQUEST DATED 6/1/00
REQUEST 11
RESPONSIBLE PERSON: **Dwight Lockwood**
COMPANY: **Kentucky Pioneer Energy**
(responding for East Kentucky Power Cooperative)

Request 11. What is the range of specifications for the coal that can be used in this gasification process? What are the specifications of the coal that will be used in this process?

Response 11. A major benefit of BGL gasification technology is that it is capable of processing a wide range of feed materials, with wide-ranging specification. Also, syngas clean up (e.g. sulfur removal) enables use of high sulfur (non-compliance) coal. Acceptable coal content can be in excess of 7% sulfur and approximately 25% ash.